AC transformer :-

An AC transformer is an electrical device that is Used to Change the voltage in AC electrical circuits.

Construction of Transformer :-

Two basic parts in Transformer Construction.

1. Magnetic core 2. Windings or coils.

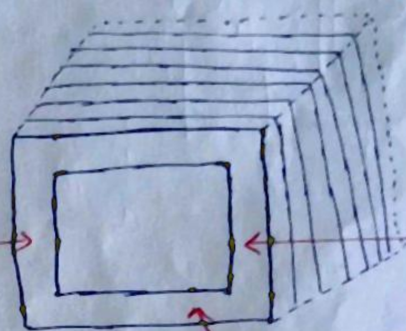
1. Magnetic core :-

→ Core provides path for magnetic flux. (ϕ)

→ Hence there are two types of losses occur in the core.

a) Hysteresis loss
b) Eddy Current loss

} magnetic losses (or) Iron losses.



fig(1)

* Now we need to construct core suchway that these two losses as low as possible.

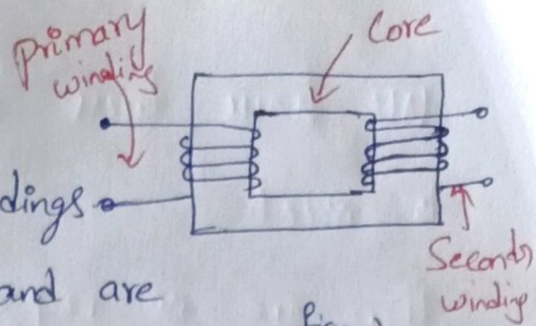
→ Generally core is made up of high grade Silicon Steel (magnetic material with high permeability) to minimize hysteres losses.

→ Earlier core is made up of iron.

* For eddy current losses reduction:→

→ Core is made upof thin laminations

2) windings (or) Coils :-



fig(2)

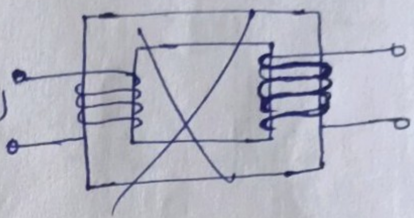
→ Electric Current passes through windings.

→ windings are made up of Copper and are wound on the limbs of magnetic core.
Windings are insulated from each other.

→ windings are Subjected to I^2R losses which are also Called as Copper losses.

* Based on the arrangment of core & winding, there are two types of transformer.

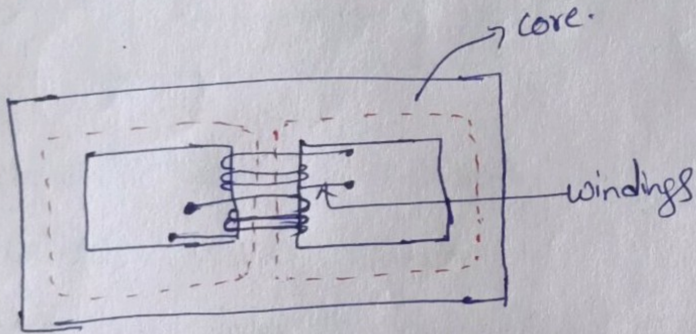
i) Core type transformer :-



Here core is Surrounded by windings (or) the winding encircles the core.

Draw fig(2)

ii) Shell type Transformer :-



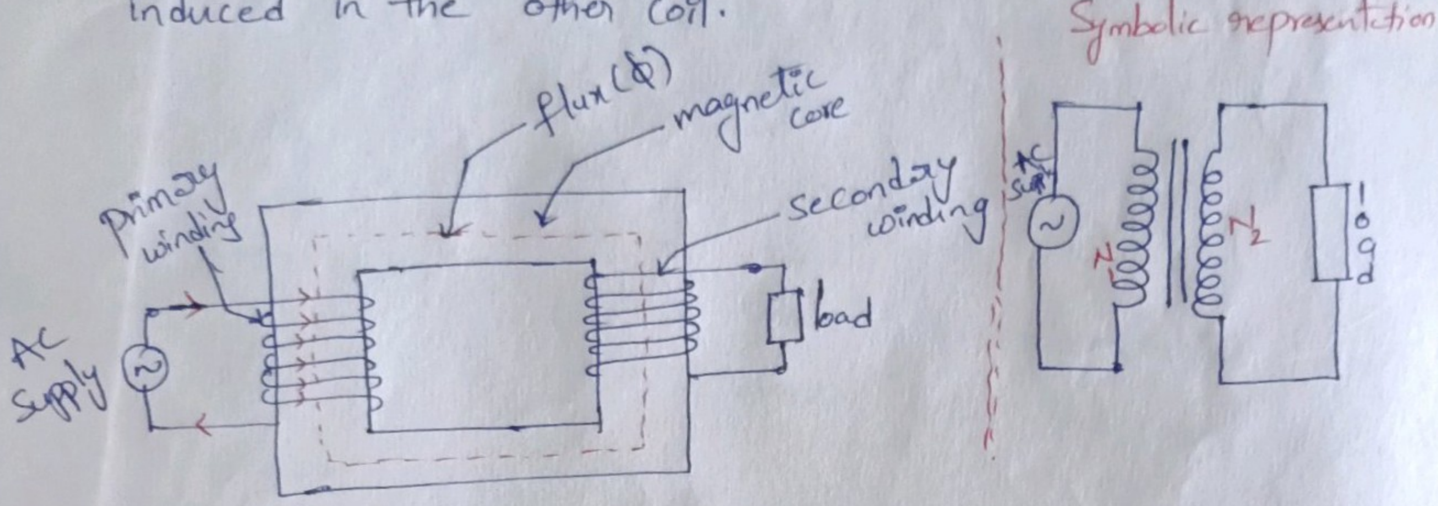
Here the core encircles the windings (or) windings are Surrounded by core.

Working principle of Transformer :-

→ Transformer works on the principle of Mutual Induction.

Mutual Induction :-

The principle of mutual Induction States that, when two coils are inductively coupled and if current in one coil changed uniformly then an e.m.f gets induced in the other coil.



→ Wherever there is a supply connected to coil, that coil is called primary winding.

→ Where ever load is connected that coil is called Secondary winding.

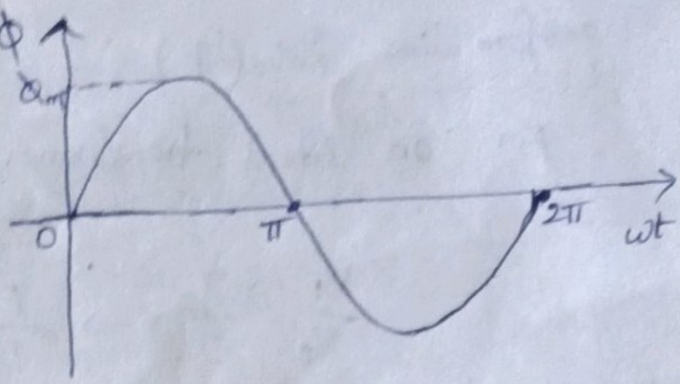
* Because of AC Supply, Current will pass through the primary winding. This current gives rise to magnetic flux through the magnetic core.

→ The magnetic flux changing w.r.t time gets linked in primary winding and E.m.f produced in primary winding. That emf is called Self induced e.m.f.

→ Same flux linked in secondary winding and e.m.f produced in secondary coil. This e.m.f is called mutually induced e.m.f.

EMF equation of Transformer :-

$\phi = \phi_m \sin\omega t$



By Faraday's law of electromagnetic induction, e.m.f induced

$$e = N \cdot \frac{d\phi}{dt} \quad -(1)$$

By len'z's law, $e = -N \dfrac{d\phi}{dt}$ $-(2)$

lenz's law :- e.m.f induced in a conductor will oppose the current which has produced the flux ϕ

E.m.F induced at the primary Side, $e_1 = -N_1 \dfrac{d\phi}{dt}$

N_1 = no. of turns in primary winding.

$$e_1 = -N_1 \frac{d}{dt}(\phi_m \sin\omega t)$$

$$e_1 = -N_1 \phi_m \cos\omega t \cdot \omega$$

$$e_1 = N_1 \phi_m \omega (-\cos\omega t) \qquad \left[\because -\cos\omega t = \sin(\omega t - 90)\right]$$

$$= N_1 \phi_m \omega \sin(\omega t - 90)$$

$$e_1 = \phi_m 2\pi f N_1 \sin(\omega t - 90) \quad -(3)$$

$$e_1 = E_{m1} \sin(\omega t + \varphi) \quad -(4)$$

Here $E_{m1} = 2\pi f \phi_m N_1$, $\varphi = -90^\circ$.

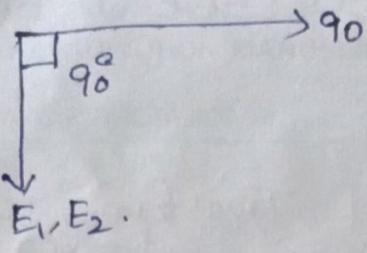
R.M.S Value of e.m.f, $\dfrac{E_{m1}}{\sqrt{2}} \Rightarrow \dfrac{2\pi f \phi_m N_1}{\sqrt{2}}$

$$\boxed{E_1 = 4.44\, \phi_m f N_1} \quad -(5)$$

Similarly, Secondary Side e.m.f, $\boxed{E_2 = 4.44\, \phi_m f N_2}$ $-(6)$

E_1 & E_2 lag flux ϕ by 90° (or) $\pi/2$

Phasor diagram :-



Transformation Ratio (k) :-

For an ideal transformer, $V_1 = E_1$

$V_2 = E_2$ and ~~$V_1 E_1$~~

$V_1 I_1 = V_2 I_2$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} \Rightarrow \frac{E_1}{E_2} = \frac{I_2}{I_1} \quad \text{—(7)}$$

From eq (5) and eq (6),

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \text{—(8)}$$

From eq (7) and eq (8),

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k}$$

K = Transformation ratio

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losses :— in a transformer :—

There are two losses occur in transformer, 1. Core losses
2. copper losses

1. Core losses : Core gets subjected to alternating flux causes core losses.

2. Copper losses :— The windings carry currents when transformer is loaded causing copper losses.

Core / Iron / constant losses

i) Hysterisis losses :— Due to Ac flux set up in the magnetic core of t/f, it undergoes a cycle of magnetisation and demagnetisation. Due to the process of magnetisation and demagnetisation there is a loss of energy which is called hystersis losses.

$$\boxed{P_h = K_h B_m^{1.67} f \cdot V}$$

K_h = Hystersis constant
P_h = Hystersis loss
B_m = Maximum flux density
f = frequency
V = Volume of core

ii) Eddy Current losses :—

The induced emf in the core tries to set up eddy currents in the core and hence responsible for eddy current losses.

$$\boxed{P_e = K_e B_m^2 f^2 t^2}$$

K_e = Eddy current constant ; t = thickness of the core.

* To avoid hystersis losses, magnetic core material is made with ∴ "high grade material silicon steel"

* To avoid eddy current losses, magnetic core will be made such way that it will consists of very thin laminations

2. Copper / I^2R / Variable losses :-

Copper losses are due to the power wasted in the form of I^2R loss due to the resistances of the primary and secondary windings.

$$\boxed{P_{cu} = I_1^2 R_1 + I_2^2 R_2}$$

Copper losses depend upon the amount of load current which can be changed depends upon the load connected.

$$\text{Total losses} = \text{Constant losses} + \text{Variable losses}$$

$$= (P_h + P_e) + I_1^2 R_1 + I_2^2 R_2$$

Efficiency of Transformer :-

Efficiency is denoted by $\eta = \dfrac{\text{output power}}{\text{input power}} \times 100$

$$\eta = \frac{\text{output power}}{\text{output power} + \text{losses}} \times 100$$

For full load,

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + W_i + W_{cu}}$$

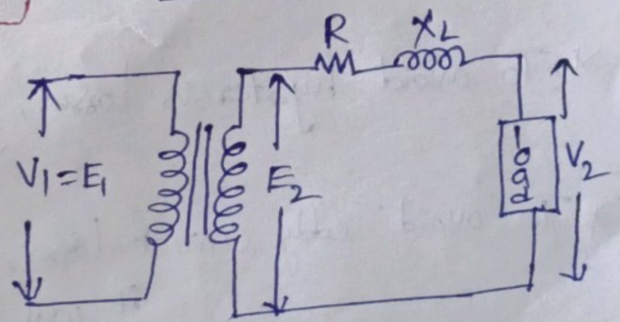
Voltage Regulation :-

The change in terminal voltage from no-load to full load at constant supply voltage w.r.t no-load voltage is known as voltage regulation of the transformer.

$$\boxed{\%\ \text{Voltage regulation} = \frac{E_2 - V_2}{E_2} \times 100} \qquad \boxed{E_2 = V_2 + I_2 Z}$$

E_2 = Secondary voltage at no-load

V_2 = Secondary voltage at full-load



1-ϕ Induction motor :-

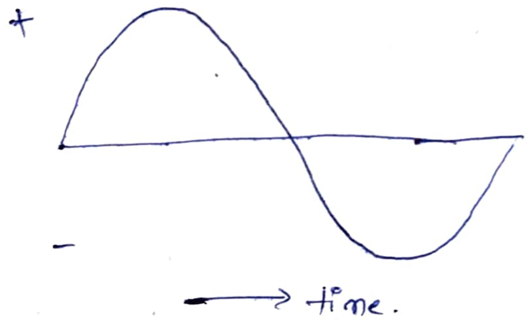
* The most common type of electric motor is the single phase type.

principle of operation :-

→ A single phase induction motor consists of a single phase winding mounted on the stator and the cage winding mounted on the rotor.

→ When a single phase supply is connected to the stator winding a pulsating magnetic field is produced.

→ pulsating field is the field which builds up in one direction, falls to zero then again builds up in the opposite direction.



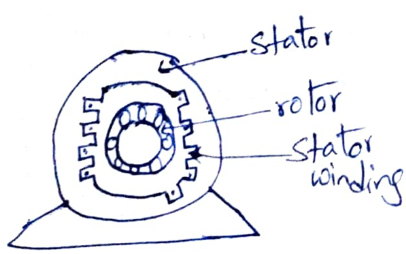
→ Under these conditions, the rotor does not rotate due to the inertia.

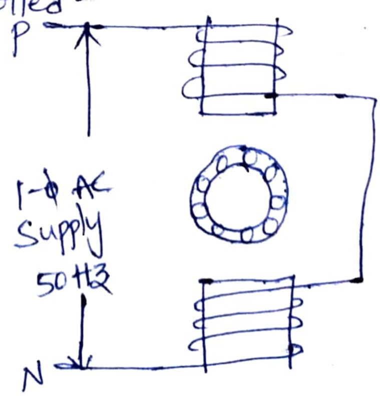
→ Therefore, a 1-ϕ induction motor is inherently not a self starting motor.

→ Inorder to start it requires some

→ Inertia means it is tendency of an object to maintain its state of rest / uniform motion.

→ However, if the single phase stator winding is excited and the rotor of the motor is started by an auxiliary means and the starting device is then removed, the motor continues to rotate in the direction in which it is started.





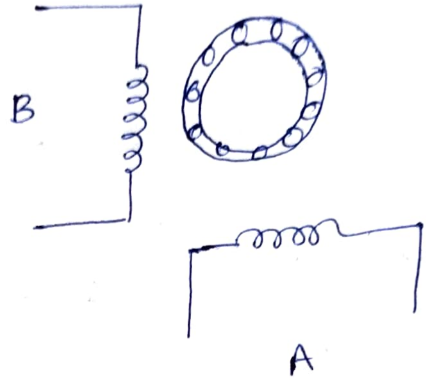
Production of Rotating Magnetic field:-

→ Consider two windings A and B so displaced that they produce magnetic fields 90° apart in space as shown in fig (a)

→ Suppose these windings produce magnetic fields equal in magnitude and 90° apart in time given by

$$\phi_A = \phi_m \sin\omega t \quad \text{---} \; (1)$$

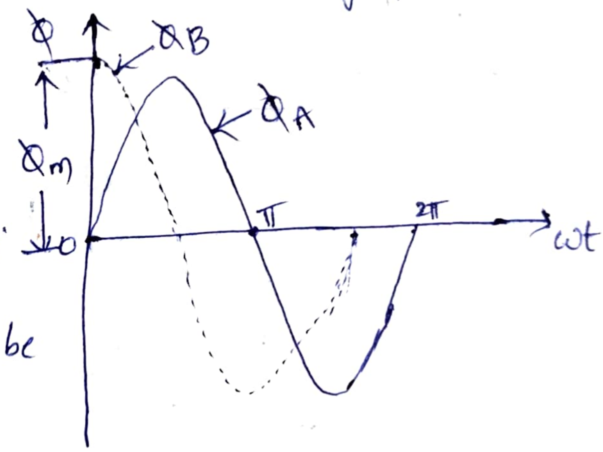
$$\phi_B = \phi_m \sin(\omega t + 90) \quad \text{---} \; (2)$$



fig(a)

→ The waveforms of these fields are shown in fig(b)

→ The resultant of these two fields is a rotating magnetic fields of a constant magnitude ϕ_m.



→ This rotating magnetic field may be represented by a phasor of constant magnitude ϕ_m as shown in fig (c).

→ **Synchronous Speed:-**

Speed of Rotating magnetic field is called Synchronous Speed

$$N_s = \frac{120f}{P}$$; f = frequency, P = no. of poles

→ This uniform rotating magnetic field produces uniform torque which tends to turning moment of rotor.

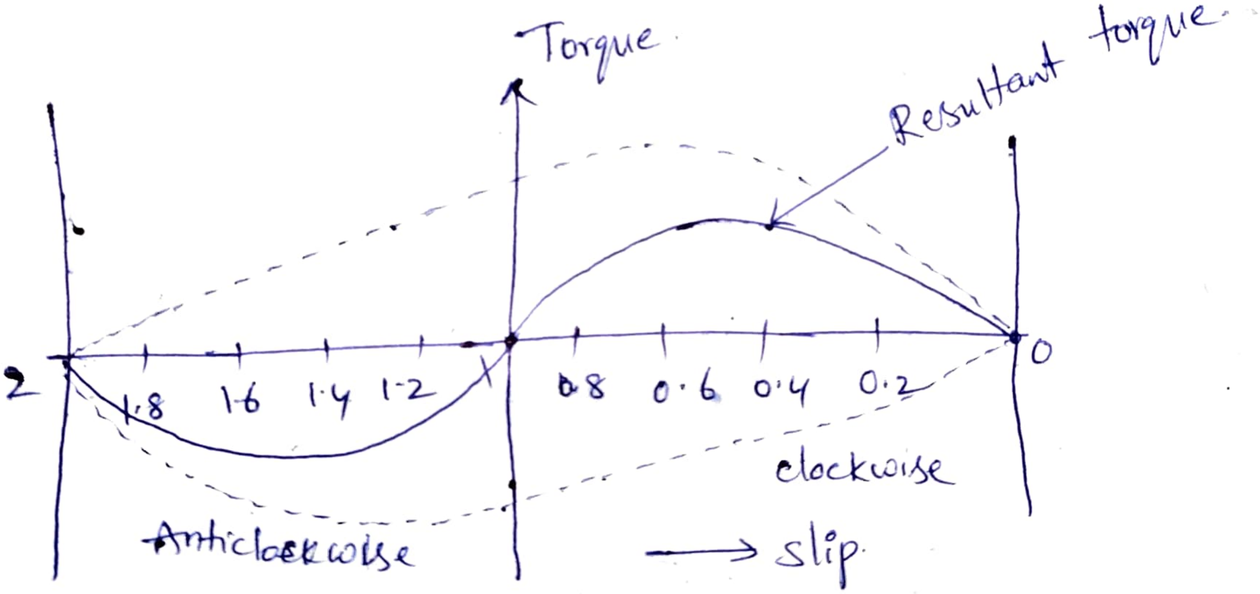
Slip- torque characterstics :-

Slip: Slip can be defined as the distinction b/w the flux Speed (N_s) and rotor Speed (N/N_r)

→ Speed of the rotor is always less than Synchronus Speed.

→ It is usually expressed as a percentage of Synchronus Speed(N_s) and represented by symbol 'S'.

$$\boxed{S = \frac{N_s - N_r}{N_s} \times 100}$$



It is known that, at Starting i.e $N_r = 0$

$$S = \frac{N_s - N_r}{N_s} = \frac{\cancel{N_s} - 0}{\cancel{N_s}} = 1$$

$S=1$, the resultant torque is Zero

∴ 1-ϕ induction motor has no Starting torque.